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Construction Engineering Research Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Visualization in Collaborative Engineering Design

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Foreword

This study was conducted for Headquarters, U.S. Army Corps of Engineers (HQUSACE) under Project 4A162720AT23, "Basic Research in Military Construction," Work Unit EC8, "Advanced Visualization."

The work was performed by the Engineering Processes Branch (CF-N), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). Part of the data gathering for this study was done by the University of Illinois at Champaign-Urbana (UIUC) under contract DACA88-96-D-0005-05 (UIUC 1-5-28789) with Patricia M. Jones, Associate Professor, Department of Mechanical and Industrial Engineering. The CERL Principal Investigator was Beth A. Brucker. Michael P. Case is Chief, CECER-CF-N, and L. Michael Golish is Operations Chief, CECER-CF. The technical editor was William J. Wolfe, Information Technology Laboratory. The Acting Director of CERL is Dr. Alan W. Moore.

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Contents

List of Tables

Tables

1 Introduction

Background

Architects and engineers create and communicate in a highly visual environment. The use of visual representation is fundamental to their "way of doing business" and has a significant impact on individual performance (Simon 1988, Norman 1993, Al-Rasheed 1997). We rarely think of visualization as a vehicle of thought, memory, reasoning—or as a mechanism for collaboration across various disciplines. Yet the way engineers and architects visualize their designs and communicate throughout the design-construction process fundamentally affects the quality and flow of work in the construction project. Architectural and engineering design takes place in a very visual culture. Architects and engineers rely on visualization in so many ways that its use is critical to their productivity.

Most electrical engineers, mechanical engineers, architects, and structural engineers begin their tasks by working individually. Collaboration across these disciplines is critical to the successful completion of the project. For example, architects need to understand the structural, electrical, and mechanical design at an early stage of the design process. They must be able to express the design concept clearly to the design engineers who carry the project to the next stage. Also, engineers and architects must collaborate with other construction professionals who will follow up during the construction process.

Differing disciplines working alone require tools that aid individual productivity. Collaborating disciplines require a different form of support to coordinate their efforts, communicate, and resolve conflicts. As yet, no solid basis has been developed for understanding how different visual representations meet the cognitive requirements of collaborating participants in the construction process. A better understanding of the role visualization plays in the design and communication process will lead to improved and innovative solutions.

Objectives

The objectives of this study were to:

1. Hypothesize a theoretical basis that describes the relationship between visualization and the cognitive and collaborative processes that occur in the facility life-cycle process
2. Empirically examine the evidence of that relationship, and potential ways to exploit the relationship to improve productivity
3. Facilitate high quality life-cycle support by identifying specific visual representations with specific collaborative tasks.

Approach

Chapters 2 and 3 provide overviews of current work. Chapter 2 provides a brief explication of conceptual approaches to visualization. Chapter 3 describes a contextual approach to the study of visualization; it argues that "good" visualization depends upon the context of the task, user, and environment. Chapter 4 summarizes work on visualization in the context of engineering design. Chapter 5 provides an overview of data collection and analysis methods. Chapter 6 describes current progress on this project's visualization studies of engineering design, specifically into building design from an architectural/engineering perspective.

Scope

This study is not meant to develop new technological solutions to visualization problems, but rather to identify which methods exist, be they simple or innovative, to describe in which contexts visual representations may be useful, and to hypothesize why those representations may be useful.

Mode of Technology Transfer

It is anticipated that this research will broadly improve collaboration strategies through better visualization in current research efforts involving the areas of Facility Delivery, Life Cycle Facility Management, and Tele-Engineering.

2 Perspectives on Visualization

This chapter describes issues and directions in the study of the role of visual representation in engineering design. This work focuses on the use of visual forms used by designers, particularly architects and engineers, in the context of the building design process.

The general issue of human-computer interaction can be considered from several points of view:

- *As a language*, human-computer interaction can be seen as a negotiated joint activity, as the establishment and maintenance of common ground (Clark 1996)
- *As a world or environment*, human-computer interaction can be interpreted as a collection of objects and their affordances (Norman 1988; Shneiderman 1987)
- *As a medium for communication*, human-computer interaction can focus on communication between designers distributed over time and space, and between system designers and end-users. The interaction is seen as a set of boundary objects to mediate cooperation (Star 1989).

These perspectives are explored in more detail below.

Linguistic Perspectives

When the human-computer interaction is seen as primarily linguistic, one analyzes the "text" (the interactive artifact) and how the "reader" (user) responds to it. This approach focuses on issues of the syntax and semantics of interaction, on the choices of how to design icons, labels, and commands; and on how to organize these items into menus, frames, etc. More abstractly, one can talk about semiotic ideas of the signifier and the signified.

Clark's (1996) work on understanding the nature of joint activity, of which language is a prime example, attempts to create a theoretical framework that incorporates both the individual cognitive and social aspects of language. Clark's

framework is very comprehensive and ambitious, and only some of the major points will be summarized below.

Joint activity is cognitive, social, and multi-layered, involving at least two agents, whose actions are somehow coordinated. This interpretation always involves the problem of meaning—the performer's intention and the audience's understanding (Clark 1996, pp 23-24). Clark follows Levison's idea of an activity type—any "culturally recognized activity," which is a fuzzily-defined category the members of which are "goal-defined, socially constituted, bounded events with constraints on participants, setting, and ... the kinds of allowable contributions" (Levinson cited in Clark 1996, p 30). In particular, Clark distinguishes between *an activity*, i.e., a time-bounded event such as a chess game, and *activity*, i.e., an ongoing process such as "teaching."

Clark's position on joint activity can be summarized as follows. Joint activity is carried out by two or more participants. The participants assume public roles that help determine their division of labor. The participants try to establish and achieve joint public goals, and may also individually try to achieve private goals. Joint activity ordinarily emerges as a hierarchy of joint actions or joint activities. Participants use both conventional and unconventional procedures to accomplish joint activity. Joint activities have boundaries (entry, body, exit) and successful joint activity has entry and exit jointly engineered by the participants. Joint activities are dynamic and may be simultaneous or intermittent, and may expand, contract, or divide in their personnel (Clark 1996, pp 37-38).

Common ground is the cumulative product of joint activity, the knowledge, beliefs, and suppositions that participants share about the joint activity (Clark 1996, p 38). Common ground consists of initial common ground (background facts, assumptions, and beliefs presupposed by participants when they entered the joint activity), current state of the joint activity (what the participants presuppose the current state is at the moment), and public events so far (what the participants presuppose have occurred in public leading up to the current state). (Clark 1996, p 43). Note that in this definition, knowledge, beliefs and assumptions are all grouped together; this slippage has been criticized elsewhere. Common ground in talk includes a discourse representation that consists of two parts: textual and situational. Part of the discourse representation is public and "on record"; some may be private. Common ground is "a form of self-awareness" (Clark 1996, p 120); participants are aware of information they each have and this awareness is reflexive—they are aware that they are aware. There is both communal (cultural) and personal common ground; the latter is based on experience.

Cooperation does not require that participants have an explicit shared goal; it may emerge from a cooperative interaction in which participants are transforming and controlling a set of objects and processes (Hoc 1998). Joint activities may have a vague goal or the goal may evolve in the process of the joint activity; joint projects may emerge out of chains of minimal joint projects (Clark 1996). However, often participants do share a dominant goal (a domain goal such as successfully controlling a system or having a successful transaction) and may also have procedural goals (e.g., "get this done quickly"), interpersonal goals, and private agendas (Clark 1996, pp 34-35). However, joint activity is local and opportunistic and emergent, even if a plan or agenda is known *a priori*.

Clark also discusses levels of activity. In this framework, four levels are distinguished: the proposal and consideration of a joint project, signal and recognition, presentation and identification, and execution and attention. Clark argues that grounding occurs at all levels of action. That is, participants try to make a thing a part of their common ground "well enough for the current purposes" (Clark 1996, p 221). In particular, this means that participants will look for positive evidence that their intentions have been carried out successfully; sufficient evidence is valid, easy to get, and timely. Also, if such closure is achieved at a higher level of activity, then it is assumed that the lower levels of activity were also successful.

The ideas that common ground represents relevant knowledge as needed—and that the context enables and constrains interpretation or understanding—are similar, but Clark (1996, p 94) does not make a commitment to a particular representational form. He discusses "human nature," lexicons, conventions, norms, scripts, and implies rules, procedures, schemata as ingredients or aspects of common ground. He focuses more on how people make inferences or believe that "some proposition p" is part of common ground. In particular, he proposes the following definition:

Common ground (shared basis)—called CG-shared

Proposition p is common ground for members of community C if and only if:

1. Every member of C has information that basis b holds
2. b indicates to every member of C that every member of C has information that b holds
3. b indicates to members of C that p "has information," is intended to cover, "knows," "believes," "assumes," "sees," "supposes," "is aware that," and so on. (This may be problematic)

From CG-shared, we can derive a CG-reflexive that eliminates the explicit notion of b by having proposition (i) refer to itself:

Common ground (reflexive)—called CG-reflexive

Proposition p is common ground for members of community C if and only if
(i) the members of C have information that p and that i

Clark rejects a third formulation of common ground that gets into a infinite recursion of mutual "having information": members of C have information that p; members of C have information that members of C have information that p; etc.

If we assume that participants in joint activity seek to do so successfully, and in fact are establishing joint commitment to engage in joint projects, then we may cast effective interaction in terms of well-coordinated joint actions and the establishment and maintenance of "solid" common ground. In particular, Clark (1996, p 289) formulates joint commitment as follows:

For A and B to commit themselves to joint purpose r:
1. Identification: A and B must identity r
2. Ability: It must be possible for A and B to do their parts in fulfilling r
3. Willingness: A and B must be willing to do their parts in fulfilling r
4. Mutual belief: A and B must believe that 1, 2, and 3 are part of their common ground.

Furthermore, participants in a joint project will adhere to the equity principle, in which the proposer presupposes a method for maintaining equity with those to whom she makes the proposal. The transfer of (social) goods creates inequities that people will always try to balance. Sometimes this transfer is accomplished by routine procedures (when the social situation is tightly circumscribed or "closed"), or it is done by regular procedures (in semi-routine situations), or it may be accomplished by novel means.

Thus, Clark provides insight into the issues of meaning and coordinated activity, which are relevant to research on collaborative engineering design and the role of visualization.

Human Factors Perspectives

A more traditional perspective on visualization is from the engineering literature that discusses human factors engineering and human-machine systems. Here, the concern is with human performance experiments to evaluate the relative

quality and use of different displays in the context of different performance tasks. Human performance is typically measured with a combination of reaction time and error measures: the best performance is typically both fast and accurate. For example, Wickens and his colleagues have done a great deal of work in aviation displays to compare two- and three-dimensional displays, and exocentric versus egocentric points of view. Their general conclusions are that the "best" display depends on the task (e.g., distance judgments versus survey knowledge) (see Wickens, Gordon, and Liu 1997). In battlefield visualization, for example, Wickens and his colleagues asked subjects to perform various judgments (e.g., distance ("how far is unit X from you?") and line of sight ("can unit X see unit Y?") in the context of one of several display conditions: 2-dimensional, 3-d egocentric, and 3-d "tethered."

Collaboration and Distributed Cognition Perspectives

Part of the developing argument in the literature is to go beyond the cognitive and cope with the political, social, and cultural aspects (e.g., Bucciarelli 1994). A fundamental aim is to understand human activity as it is produced in the context of certain cultural/historical traditions, goals, and tools. To account for human performance in a systematic and empirical manner, we need to go beyond the visual qualities of objects (e.g., by counting how many times people use two-dimensional or three-dimensional representations) to examining what objects are used for, and to understand how they communicate intention, support tasks, and form the basis for collaborative work on design teams. Thus, our philosophical basis for this inquiry comes from activity theory, distributed cognition, human communication and language, and engineering psychology (e.g., Clark 1996; Nardi 1996; Hutchins 1995; Wickens, Gordon, and Liu 1997; Wickens 1992).

The notion of cognition being distributed over people, artifacts, and time and space is the kernel of the idea of distributed cognition (Hutchins 1995). That is, cognition is not just what takes place "in the head"; we rely on and improvise onto our environment to support memory and reasoning, for example, with adhesive notes, standard operating procedures, organizational structures, the physical layout of control rooms, etc.

The concept of boundary objects (Star 1989) has been used to represent the malleable identities of objects shared across different work activities. A boundary object is an object that inhabits multiple partially overlapping social worlds, and has enough common structure to be shared across worlds, but yet is also adaptable enough to support effective local action in a particular world (Star 1989; Star and Griesemer 1989). Boundary objects can be a means of coordinating the

activity among distributed heterogeneous users, and therefore the concept lends itself readily for facilitating distributed cognition (Hutchins 1995; also see Robinson's (1993) discussion of "common artifacts"). Thus, the creation and management of boundary objects is a key process in developing and maintaining meaningful representations across intersecting social worlds (Star and Griesemer 1989; Auramaki, Robinson, Aaltonen, Kovalainen, and Tuuna-Vaiska 1996).

Star (1989) identifies four types of boundary objects: repositories, ideal types, terrain with coincident boundaries, and forms/labels. Repositories are "ordered piles of objects that are indexed in a standardized fashion. They deal with problems of heterogeneity caused by differences in unit of analysis." An ideal type is an abstract, vague, and adaptable object. Terrain with Coincident Boundaries are "common objects which have the same boundaries but different internal contents." Forms and Labels are "are standardized indexes which can be transportedver long distance and convey unchanging information. Labels and forms may or may not come to be part of repositories" (Star and Griesemer 1989, pp 410 - 411).

Chin's (1997) dissertation focused on three aspects related to using the idea of boundary objects in collaborative systems design: (1) looking for "naturally occurring" boundary objects in the workplace (e.g., the Environmental Impact Checklist that the environmental office created in an attempt to solicit feedback from engineers), (2) design of a series of user interfaces organized around two key boundary objects of "project" and "building," and (3) an exploration of the dynamic aggregation of information in the context of a joint activity.

Synthesis

It may help to consider a multi-leveled approach to theorizing about visualization in the context of various cognitive tasks related to design. If one considers design as a collaborative process shared between participants of differing backgrounds, skills, and agendas, then we can characterize their practice simultaneously on levels such as those listed in Table 1.

Table 1. Examples of the application of a multi-leveled approach to visualization.

Level of Analysis	Example Inquiries
Material	Mix of paper and computer tools Whiteboard vs. paper Perspective vs. ortho Icons, symbol sets, "visual languages" that are written
Cognitive	Semantic categories of things being designing and design process itself (obviously related to icons, symbols) Attention and inference in performance
Social/Communicative	Establishment of common ground with boundary objects; or management of boundary object gives rise to common ground? Communicative functions of visual representations and how they are produced (e.g., how do I build an argument visually by showing you effects over time, etc.) Organizational roles, power and authority, politics

This formulation is reminiscent of the abstraction hierarchy representation proposed by Rasmussen (Rasmussen, Pejtersen, and Goodstein 1994). The abstraction hierarchy is a situation-independent inventory of a work domain that is structured along five levels of abstraction: purpose, value/priority measures, general functions, activities, and material forms/tools. An abstraction hierarchy is frequently paired with a representation of levels of aggregation of a system (e.g., system, subsystem, component levels) and thus an abstraction-aggregation hierarchy forms a conceptual space through which actors engage in activities.

The original versions of the abstraction hierarchy were derived from verbal protocols collected by Rasmussen while he observed process control operators and electronics troubleshooters doing their work and talking aloud about their reasoning processes. Rasmussen's insight here was to create the abstraction-aggregation hierarchy as a space through which traces of problem solving could be shown. In this formulation, the abstraction hierarchy was of the "plant"; e.g., the abstraction hierarchy depicted purposes, functions, and material forms of the nuclear power plant, the process control plant, etc.

However, in Rasmussen's more recent work, he has broadened the concept of an abstraction hierarchy to include the entire work domain; e.g., not just the nuclear power plant (the physical system), but the work domain of nuclear power plant operations. Furthermore, Rasmussen sees this analysis as just the first step in a complex set of analyses that later include activities, organizational roles, etc. (The entire discussion is included in his book [Rasmussen, Pejtersen, and Goodstein 1994]). The aim of work domain analysis is "to produce a generalized representation of the "work domain" in terms of its inventory of objectives, functions, activities, and resources—all of which constitute the elements of the

landscape in which the staff operates" (Rasmussen, Pejtersen, and Goodstein 1994, p 35). The abstraction hierarchy is a means-end, situation-independent description of the work domain with the following five levels of abstraction:

- purposes of the work domain and constraints imposed by the environment
- value and priority measures; also topology of flow (of materials, information, people)
- general functions
- activities—more specific, object-based activities
- material form—related to physical appearance, location, etc.

Rasmussen provides a number of examples of (sketchy) abstraction hierarchies in the book. For example, on page 47, the work domain of hospital care (as opposed to hospital administration or hospital medical research for cures) has top-level goals of patient well-being and physical and psychological care, with attention to overall constraints of public opinion and legal and economic constraints. Second, the priority/value/flow level includes flow of patients according to treatment and load on staff and facilities. Third, general functions include board and lodging, hygiene, and transportation. Fourth, activities include monitoring, treating, moving, and cleaning. Finally, the fifth level, material/physical, includes facilities and equipment and inventories.

In reviewing literature on building design (e.g., the *Architect's Handbook of Professional Practice* published by the American Institute of Architects (AIA) and *the Building Systems Integration Handbook*), it is striking how many taxonomies already exist to describe this domain. The AIA handbook includes Document D200, Project Checklist, organized around the sequential design process of predesign, site analysis, schematic design, design development, construction documents, bidding or negotiation, construction contract administration, and post-contract. The Building Systems Integration Handbook organizes performance criteria into a matrix, in which the rows represent perspectives (Spatial, Thermal, Air Quality, Acoustical, Visual, and Building Integrity) and the columns represent classes of human needs (physiological, psychological, sociological, and economic).

In a brainstorming session to develop an initial abstraction hierarchy, the research group used some of these distinctions to arrive at a first pass for an abstraction hierarchy (AH) for the work domain of Building Design, shown in Table 2 below.

Table 2. Initial abstraction hierarchy for building design.

AH Level	Building Design elements
Purposes/Constraints	Satisfy user needs; Satisfy owner needs; Satisfy community needs
Abstract functions/ Priority Measures	Government regulations; Code; Comfort; Usability; Shelter Safety
General Functions	Identify scope, user needs; Ensure structural integrity Review; Communicate concept; Backcheck Design; Identify conflicts
Activities	Develop criteria; Drawing; Structural analysis Cost estimation; Energy analysis; Conflict resolution
Material form/ Tools	MDS/CAD; Paper drawing; Structural analysis tools Cost estimating tools; Energy analysis tools

However, as the group developed its ideas further, it began to think it needed an AH for every major design phase. Therefore, the group started brainstorming on an AH for the work domain of Predesign. Table 3 shows the current results.

Table 3. Initial abstraction hierarchy for predesign.

AH Level	PreDesign elements
Purposes/Constraints	Establish relationship between user, owner, designer Establish common vision of design intention
Abstract functions/ Priority Measures	Health; Safety; Welfare Spatial; Thermal air quality; Acoustical; Visual Building Integrity; Style; Cost-effectiveness Timeliness; Regulatory constraints
General Functions	Determine building requirements Determine budget Determine timeline
Activities	Activity analysis; Permits/zoning/code analysis Physical space analysis (blocking and sinking(?)) Spatial layout; Facility survey; Site survey
Material form/ Tools	Architectural programming document MDS; Design guides; Standard designs Preliminary budget; Preliminary schedule Checklists; Drawings; Sketches

Hence, the researchers used the human needs outlined previously as categories of values and priorities. Interestingly, it took the group a while to arrive at the purpose level—it started working on items that we later decided were general functions.

The next step in developing an abstraction hierarchy is to link items between levels. This task still remains to be performed. Researchers should also develop a suite of AHs for the life-cycle process as well as develop aggregation hierar-

chies to go along with each AH. The next step is validation, which typically consists of subjective agreement from other domain experts not involved in the construction of the AH. Finally, researchers can use the AH representations to provide guidance on the interpretation of collaborative verbal protocols (as Rasmussen did in his original work in the 60s and 70s) and on alternative approaches to visualization (e.g., ecological interface design, in which higher-order invariants are visualized directly on a user interface (Vicente and Rasmussen 1992).

Chapter 3 considers another input to the analysis process: characterizing "good" visualization.

3 What Is "Good" Visualization?

"Good visualization" is context-dependent. In human factors, "context" is typically considered with respect to the intended user population, tasks, and environment. For example, the intended audience might be the general public, children, users who are color-blind or cannot use their hands to type, etc. The task context is also critical; much human factors research looks precisely at the interaction between task and displays/controls. For example, Wickens and his colleagues have done a great deal of work in aviation displays to compare two-dimensional and three-dimensional displays and exocentric versus egocentric points of view. Their general conclusions were that the "best" display depends on the task (e.g., distance judgments versus survey knowledge) (see Wickens, Gordon, and Liu 1997). Finally, the intended deployment environment is also important—what software and hardware platforms, hardware input and output devices, etc. will be available to users.

Even so, some high-level design guidelines have been used in human factors (Norman 1988; Wickens, Gordon, and Liu 1997), graphics design (Mullet and Sano 1995; Tufte 1983, 1990, 1997), and usability engineering (Nielsen 1998).

For example, Norman (1988) describes a simple model of user-world interaction in which a constant cycle recurs between the user's goal, which leads to intention, action specification, and execution. This in turn has an effect on the world that triggers the user's perception, interpretation, and evaluation of that new world state with respect to goals. Based on this model, Norman argues for high-level design principles such as:

1. Visibility
2. Natural mappings
3. Providing a good conceptual model
4. Feedback and error prevention.

Similarly, Nielsen (1998) proposes 10 usability heuristics:*

* for more information, also see http://www.useit.com/papers/heuristic/heuristic_list.html

1. Visibility of system status
1. Match between system and the real world
2. User control and freedom
3. Consistency and standards
4. Error prevention
5. Recognition rather than recall
6. Flexibility and efficiency of use
7. Aesthetic and minimalist design
8. Help users recognize, diagnose, and recover from errors
9. Help and documentation.

From a graphics design perspective, Mullet and Sano (1995) organize "do's and don'ts" of artifact design (graphical user interfaces, telephones, kiosks, etc.) around principles such as elegance, simplicity, scale, contrast, proportion, visual structure and organization, image, and style.

From a communications perspective, we can also analyze visual representations from the point of view of the audience invoked versus the audience intended, i.e., what the designers' intention was in constructing this representation, and whether the members of the audience are constructing inferences as intended.

Other aspects on which one can evaluate visual representations are their ability to support navigation and search, and their cost of creation.

However, in adopting the ideas behind distributed cognition and situated action (Hutchins 1995; Suchman 1987), this study also has an interest in the analysis of "context" in terms of social, cultural, and political factors, including the presence of pre-existing plans or procedures, cognitive tools, organizational structures, etc. This is described more fully in the next chapter.

4 Visualization and Engineering Design

Engineering design takes place in a very visual culture. Ethnographic studies of engineering design have noted how engineers create visual representations of their hypotheses, designs, etc. and how these are annotated and used to mediate communication (Bucciarelli 1994; Ferguson 1993). Ferguson argues for the importance of learning good judgment skills through visualization. Of course there are issues of how the visual representation "speaks" to the observer (cf. Tufte 1983, 1990, 1997). Certainly, graphs can have distorted scales, be cluttered, emphasize the "wrong" things, and so on.

Bucciarelli (1994) argues that design is a social process and that engineering designers are a subculture. In his ethnographic study of three design projects, he uses the concept of "object worlds" as a way to characterize how the design process is typically characterized—organized around the object being designed—and contrasts that with a broader picture that takes into account social context and historical setting. Distinctions between technology and "politics" are often blurry. While one can analyze the role of visual representations in design as "speech acts" that form parts of a design narrative, Bucciarelli argues that one cannot really understand them without the surrounding context, and that these representations are another means by which the "object world" subculture expresses itself:

> We can think of these sketches drawn in the course of object-world activity as "speech acts," as part of the process of making and telling stories. Some are worked up and become permanent ingredients of the design; others are more transient evocations. There is little in them that tells you about their significance and role in the negotiation of design options, what followed the discourse of which they were an integral part, or how they stimulated their authors or audience to adjust their own thoughts and practices. Note, too, that one and the same drawing may be used on more than one occasion, layered with new meanings, shadings, comments, and erasures. In this case it might be best understood as an entirely new drawing. ... The correct reading of all these drawings requires knowledge of the local dialect of the object worlds to which they belong and also of the context of their moment in use. ... [T]hey are sparse and abstract, symbolizing the essential features of whatever it is they are

> about. Although many details are left out, the important object-world content of these figures is there in relief. All show deterministic configurations in space and time. If alternative routes are possible in a flow diagram, these appear explicitly as options. All possible trajectories or states are included in the representation. All causes and effects are displayed. There is closure, and the system is bounded. All is clear, unambiguous, and certain, at least if one is capable of right thinking, reading, and speaking within the relevant object worlds (Bucciarelli 1994, pp 97-98).

Similarly, Henderson's analysis of visual representations in engineering practice is grounded in participant observation and ethnographic techniques. It demonstrates how central visual representations are to engineering work (Henderson 1999). Visual representations are boundary objects that organize work and affect those who participate in the design process. The ability of different participants to read them at different levels also contributes to their usefulness as a coordination mechanism. Henderson also discussed the role of tacit knowledge in design and looked at the mix of paper- and computer-based representations that are actually used in practice; indeed, codified, explicit knowledge is just the kind that can be implemented computationally, while tacit knowledge is by definition uncodified and hence not amenable to explicit computational support. However, both codified and uncodified knowledge is needed to actually do design work. While Henderson points out that there is no one best way to implement computer-based systems, she does provide examples of how a rigid design process enforced with software can "destroy practices that are important for specific aspects of design activity ... [these] rigid models ... break down social communication practices that normally repair the frequently occurring problems and misunderstandings that are part of the work process in a world of messy practice" (Henderson 1999, p 8). Henderson also introduces the idea of "conscription devices" to explain "the intersection between the roles of inscriptions and boundary objects, which facilitate distributed cognition in team design work" (Henderson 1999, p 9). Finally, she explores why visual representations are so powerful and argues that visual representations are "meta-indexical"; they form a "holding ground" where codified and uncodified knowledge can meet, and where various forms of tacit knowledge (visual, kinesthetic, mathematical, experiential) are brought into play.

John Gero's work, in contrast, is grounded in the cognitive tradition of individual verbal protocol analysis and cognitive problem-solving models (Gero 1990, 1998; Gero and McNeill 1998; McNeill, Gero, and Warren 1998; Purcell and Gero 1998; Suwa, Gero, and Purcell 1998; Suwa, Purcell, and Gero 1998). There are possi-

ble advantages of the use of content-oriented over process-oriented approaches in the analysis of verbal data (Suwa, Gero, and Purcell 1998). With a content-oriented approach, one tries to account for meaningful context instead of forcing data to fit into an abstract, generalized, decontextualized psychological model. On the other hand, the appeal to a fairly strong cognitive psychology orientation has both advantages and disadvantages. An advantage is that the cognitive psychological orientation provides clearly defined coding schemes and implications for computational models of cognition. A disadvantage is that, with this model, one chooses not to represent most elements of social, cultural, and historical knowledge. A compromise would be a multi-leveled approach to analysis, perhaps as sketched in Chapter 2.

5 Strategies for Data Collection and Analysis

Wickens, Gordon, and Liu (1997) describe a range of experimental and observation techniques available. The list below ranges from naturalistic to controlled strategies, with tradeoffs of relevance, validity, and reliability.

- *Ethnography / Naturalistic Observation / Field Studies*: Data include archives, notes from observations, and video and audio recordings of natural behavior.
- *Task Performance with Questioning*: Observe natural performance but intervene to ask questions.
- *Interviews and Surveys*: May be part of ethnographic work.
- *Scenario / Simulation Studies*: Practitioners participate in realistic but controlled exercises. Data include concurrent or retrospective verbal protocols, video and audio tape, and notes. Dorner (1997) describes example simulation-based scenarios that abstract out general cognitive elements of interest.
- *Controlled Laboratory Studies*: Generic tasks with some resemblance to real-world practice with highly controlled manipulations of factors. Laboratory studies employ the classic experimental approach.

Each of these methods is described in more detail below. Also see Kirwan and Ainsworth (1992) and Hackos and Redish (1998). For all methods, appropriate access to participants is critical – most institutions have a Review Board to safeguard the privacy and health and welfare of human subjects, even if those "subjects" are not in the laboratory but are just being observed in the workplace. Therefore, before any such research endeavor, the researcher must: (1) get the research proposal approved by the institution's review board, (2) gain legitimate access to human subjects in their own organization (e.g., meet with managers and get signed approval), and (3) assure all subjects that their participation is voluntary, that the research poses no foreseeable risks, and that their participation in the research is unrelated to their grades, job performance ratings, and the like.

Ethnography

Natural observation of a culture "in the wild" is one method for studying it. The term "ethnography" encompasses a range of philosophical perspectives and more detailed methods, but the general idea is to gain access to a site in which the "natives" (i.e., engineering designers, architects, etc.) are in their "natural habitat" and collect information about how activity actually occurs. Data collection methods include informal interviews, unobtrusive observation of meetings and work, archival work (e.g., getting copies of reports, memos, drawings, etc.), and a review of computer logs and video and audio-tape data. The latter categories lead to questions of privacy, and so special permission is needed to access such detailed data. The skills that researchers must employ are: (1) being polite and unobtrusive, (2) taking good notes, and (3) doing homework on the vocabulary, procedures, and other standardized parts of the work domain so as to avoid asking "stupid" questions. One variant technique that is not unobtrusive is participant observation, in which the researcher becomes a participant in the work process or culture. One famous example is a researcher who moved to a neighborhood in order to study it. In the context of engineering design, this might mean that a CERL researcher is "really" working on a design project, but at the same time reflects on the activity, takes notes, and treats the experience as research.

While an obvious advantage of ethnographic work is the high degree of face validity and construct validity (i.e., the researcher is "really" studying "real life"), there are problems related to generalizability, sampling, and perspective—how can you learn something from one work context that transfers to another? And how can you be sure that the behavior you happen to see or experience is representative? And how do you overcome issues such as the Hawthorne effect, in which the very fact of your presence and/or data collection strategies may disturb or alter the normal course of activity?

Task Performance with Questioning

This technique can be done in the laboratory with a simulated task, or in a natural setting during "real work." It is deliberately more intrusive that passive observation, but the tradeoff is that you may uncover more of the phenomena of interest. Basically, instead of just observing a person at work or solving a problem, the researcher interrupts with questions such as "So why did you just do that?" and "Can you explain your reasoning here?" This method has the same advantages and disadvantages as ethnographic work, with the additional con-

cern that such probes may disrupt performance and change the nature of the work.

Interviews

Interviewing participants is a common technique and also is a good first step after the researcher has done a reasonable amount of background work (archival analysis). Interviews are structured conversations in which the researcher asks questions and the respondent answers. Interviews are typically conducted face-to-face, and the interviewer follows a pre-set, written protocol of questions. Sometimes informal interviews may be very unstructured. Other interviews may be extremely formal and structured. The appropriate degree of structure designed into the process depends on the goals of the researcher. Typically, early in a study, a more informal and exploratory stance is helpful. Later on, with particular issues of interest, a more structured approach may be desirable.

The degree to which interviews are reliable, valid, and useful rests on several issues:

- the wording of the questions themselves
- the conscious or unconscious ways in which the interviewer may bias the subject's answers (e.g., by being abrupt, acting more or less interested, using different voice tones, making eye contact, etc.)
- the social situation of the interview (e.g., if the setting and circumstances are friendly or not)
- whether subjects answering questions in the ways they think they should rather than by giving "the truth"
- the fact that subjects are not in their work context during the interview so that asking them for detailed explanations of how they perform is usually not very helpful.

Surveys and Questionnaires

Surveys and questionnaires are written documents that contain questions that subjects are supposed to answer. These may be administered on paper in face-to-face meetings, on paper sent through the mail and to be mailed back to the researcher, or even on the Web or over e-mail. Questions may be closed-form (e.g., making a choice from a menu of options) or open-ended (e.g., writing thoughts on some issue). Closed-form questions may be multiple choice, or using a Likert scale for ratings (e.g., "Please rate your satisfaction with the MDS sys-

tem on a scale from 1 to 5, where 1 = very dissatisfied, 2 = dissatisfied, 3 = neither satisfied nor dissatisfied, 4 = satisfied, and 5 = very satisfied"), or may ask subjects to rank-order items.

The obvious advantages of survey and questionnaire instruments are that they are inexpensive to administer and easily scaleable to thousands of people. A number of issues must be addressed. In addition to issues of bias in wording of questions, the desire of respondents to be socially acceptable as in interviews, and the issue of interviewer bias if the survey is administered face-to-face, there is the issue of respondent compliance if surveys are mailed or e-mailed. In other words, the intended audience may not respond at all to a survey request, or may only complete a survey partially. It is not uncommon to have 25 percent or less of the respondents reply to a survey. A number of strategies exist for increasing the response rate, including: (1) administering surveys face-to-face or over the telephone, which is more labor-intensive and not as scaleable to large populations, (2) offering incentives to participants, such as drawings for prizes or free gifts, and (3) targeting surveys carefully at relevant participants who would be likely to respond.

Scenario-Based Simulation Studies

Often a good compromise between the messiness and access problems of doing research "in the real world" versus the potential rigidity and lack of validity in controlled experiments is the scenario-based simulation study. In this method, researchers have participants come into the laboratory and work on realistic scenarios. Participants know they are not "really" doing design for a real project, or flying a real aircraft, etc., but if the scenario and the simulated world have high enough fidelity, then the researchers may often feel comfortable with the conclusions learned from such studies.

To carry out such a method effectively, the researcher must spend a great deal of time carefully constructing scenarios and supporting materials/simulations that will reflect the points of interest in the real activity. Typically, researchers work with real practitioners to construct scenarios and simulated task environments, and then have other practitioners be the subjects to be studied. This is so the codesigner of the scenario is not involved as a subject, which can contaminate results.

The kinds of data collected from simulated scenarios may include: (1) videotape and audio tape of activity, (2) computer logs of user actions and simulation events, (3) copies of sketches, notes, and other things generated during the sce-

nario, and (4) concurrent or retrospective verbal protocols, in which the subjects are asked to either talk aloud during performance, or describe themselves afterwards. The analysis of verbal protocols itself is a mini-research field, and questions exist about the extent to which verbalization interferes with task performance as well as methodological questions on how to unitize (i.e., break down into pieces) and code (i.e., interpret the units) verbal protocols in a reliable and valid manner. It is common to administer questionnaires after performance as well, to gauge opinions and other points of interest.

Controlled Experiments

Finally, the classic experimental psychology approach to studying human performance is to create a much more rigid, repeatable structure of activity in the laboratory, and have subjects perform these tasks. Typical data are reaction time and error rates, and the typical concern is with statistical reliability and validity and the appropriate number of subjects and trials to test statistical hypotheses. The deliberate choice is to provide a more generic, abstract, decontextualized space of work in the belief that what is learned in such an experiment will generalize to many contexts. Researchers trained in sociology or anthropology tend to disagree with this assumption on principle—the alternative stance being is that, by removing context, one also removes all the interesting features of performance.

From a cognitive systems engineering point of view (e.g., Rasmussen, Pejtersen, and Goodstein 1994), context is crucial. Therefore, cognitive systems engineering methods have emphasized ethnographic and scenario-based simulation studies, with supplemental interviews and questionnaires, in order to understand performance in context. This study's first step in this regard is described in the next chapter.

6 Current Work on Empirical Studies of Engineering Design

Appendixes A and B include notes from a preliminary ethnographic study of a Charrette process conducted at Fort Hood. Notes and audio and video tapes were made of an intensive 1.5-day meeting that involved intensive negotiation and requirements definition on the part of the user representatives. Elements of what Bucciarelli and Henderson have pointed out were apparent: the messiness of the process, the use of a mix of paper and computer representations, the flexible incorporation of sketches into the process of discussion. One point of interest here was the use of the Modular Design System (MDS) in the process. One of the participants is an MDS proponent, and this certainly influenced the course of the design process.

Another part of this empirical work was a preliminary analysis of MDS. On 7 August 1998, two CERL researchers reviewed the MDS system for several hours. Again, as has been noted by other authors, industry standards or lack thereof certainly influence the form of computer-based design systems, and the constraints on activity in the design process may impact how well users can perform in this environment. The following discussion points out both some issues on constraints and details the kinds of objects available for manipulation by MDS users.

MDS uses Army Corps of Engineer symbologies and standards, which are notably different from other commercial packages or even software used in other branches of the military. The basic process of using MDS is generally as follows:

1. Create a New Project and specify its features (e.g., name, English or metric units, etc.).

2. Create a New Building (projects can have multiple buildings).

3. When adding a building, you must specify building code, name, type and number of floors.

4. You must create a space layout first. Once done, you cannot go back.

5. Step 4 launched MicroStation,™ which has a custom MDS toolbar added in. Choose scale and draw as usual. You must generate floor perimeter to proceed.

6. Then you can flexibly choose among items on a Discipline selection list (which are associated with Drawings selection list):

A. Architectural

i. Breaks down to n^{th} floor architectural plans and Roof Plan. When doing a Floor Plan, in MDS menu have Palettes for Walls, Doors, Windows, Rooms, Items, Symbols, Dimensions, Measure, Text, Sheet Set Up.

a. Items are generic things.

b. Symbols are North-Up Arrow, Scale, Match Line, Leader, Break, Change.

ii. Roof Plan has Palettes for Columns, Roofs (including Roof Drain), Measure, Symbology (same as "Symbols" previously), Linear Dimension, Text, Sheet.

B. Mechanical. There are Mechanical Plans for each floor. Palettes for Ducts, Devices, Equipment, Symbology, Dimension, Text, Sheet Set Up.

i. Devices are Diffuser, Damper, Pipe, Valve, Elbow, and "Item."

ii. Equipment Palette includes Schedule Design Criteria, Place Air Separator, Place Air Handler, Place Expansion Tank, Place Unit Header, Place Fan, Place Fan Coil, Place Pump, Place Return Fan, Place "Item Equipment," Place Split System, Place Filter, Place Sound Attenuator, Place Cooling Tower, Place Reciprocating Chiller, Place Centrifugal Chiller, Place Boiler, Place Infrared Heater, Place Makeup Unit, Place Air Terminal, Place "Equipment." (Actually, some of these choices say "Place" and other say "MDS Place.")

C. Electrical.

i. Electrical plans for each floor include Lighting Plan and Power and Communication Plan. Lighting Plan Palettes include Fixture, Wiring, Items, Symbology, Dimensions, Text, Sheet Set up.

a. Fixture Palette is Place, Move, Change, Delete.

b. Wiring Palette is Place Wire, Place Wire by End Points, Place Conductor, Place Home Run, Delete Wire, Place Switch, Delete Switch.

ii. Power and Communication Plan Palettes are Wire, Communication, Power, Equipment, Disconnect, Fire, Items, Symbology, Dimensions, Text, Sheet Set Up.

a. Wire Palette is same as above in Lighting Plan.

b. Communication Palette is shown as just one item: Place Communication Symbol.

c. Power Palette is shown as: Place Power Item, Place Motor, Delete Power Item.

d. Equipment Palette is shown as: Place Panel, Place Transformer, Place MCC, Delete.

e. Disconnect Palette is shown as: Place Disconnect, Place Disconnect Switch, Delete.

f. Fire Palette is shown as: Place Fire, Place Fire Panel, Delete.

D. Structural.

i. Foundation/Ground Floor Plan.

a. Footing Palette: Place Column, Place Column Footing, Place Wall, Place Wall Footing, Place Joints, Delete.

b. Framing Palette: Change Framing Cell, Place Framing Cell, Calculate Gravity Loads, Size Beams/Girders, Place Beam/Girder, Place Brace, Frame ID, Beam/Girder ID, Delete.

c. Items Palette: much more specialized; a large list that includes 18-in. Block Out at Edge Column, 18-in. Block Out at Int Column, Elevator Ground Floor Plan, Stair 1 - Ground Floor, Stair 1 - Second Floor/CMU Walls, Vault VT - 1, 25-in. Slab/.6-in. - 28ga/6x6, W1, 4xW1.

d. Slab Palette: Align Saw Joint, Place Slab Joint, Place Saw Joint (there is no delete here!) Symbology, Linear Dimensions, Text, Sheet Set Up.

ii. Roof Framing Plan: same Palettes as above for Foundation/Ground Floor Plan.

E. Plumbing - not selectable?

F. Furniture. There are n^{th} Floor Furniture Plans, Systems Component Plan, Systems Panel Plan.

i. Furniture Plan Palettes: Furniture, Items, Symbology, Dimension, Text, Sheet Set Up.

ii. Furniture Palette: Place Furniture, Place Systems, Place Accessory, Place Tag, Move Furniture, Change Furniture, Delete Furniture.

iii. Items is a selection list.

iv. Systems Component Palette and Systems Panel Palette same as above.

G. Sheet Preview.

It was interesting to note how the design of MDS reinforces boundaries among the professional disciplines. Henderson (1999) also discusses the codification of knowledge as a historical and political process to provide privileged access to certain areas of knowledge. Also, note how MDS does have some constraints in the process: space layout must be done first and cannot be undone or revisited. This may be another opportunity for practitioners to work around.

7 Summary and Recommendations

Summary

This study anticipates improving collaboration strategies through better visualization based on the notion that such an improved understanding would lead to innovative visualization solutions and problem-solving procedures. This research explored current literature on visualization in engineering design and has presented perspectives on visualization from several points of view: as a language, as a world or environment, and as a medium for communication.

This work hypothesizes that good visualization depends on a contextual approach, that is to say, good visualization depends upon the context of the task, user, and environment. While the "ethics of visualization" involves an appropriate, relevant, undistorted view of data; the relationship of visualization to cognitive and collaborative processes focuses primarily on the user and the tasks.

The study has established a theoretical basis for the relationship of visualization to the cognitive and collaborative process that occurs in the facility life-cycle process through a presentation of a range of experiment and observation. The protocol data presented represents a valuable source, which may be used to support further studies on visualization in collaborative engineering design.

The study also presented the roles of visualization in collaborative engineering design, specifically emphasizing ethnographic and scenario-based simulation studies, with supplemental interviews and questionnaires. Finally, the study established a firm theoretical understanding of the relationship of visualization to the cognitive and collaborative process that occurs in the facility life-cycle process through a presentation of a range of experimental and observation.

Recommendations

A great variety of interesting substantive questions exist in this field. A description of opportunities for further research follows.

Some early brainstorming on issues from August 1998, suggested the following topics based on the assumption that we are interested in scenario-based simulation studies:

- *User population*: In terms of discipline or expertise, choices to be made are whether to focus on architects or mix of architects, mechanical, structural, and electrical engineers. This choice will depend on what tasks are of interest.
- *Tasks*: Depends on user population. Can be framed in terms of the existing design process; such as conceptual design, 65 percent design, but needs to be broken down more specifically, e.g., by subsystem such as roof design or HVAC design, or by cognitive task such as navigation, distance judgments, inspection/review, search for conflicts, etc.
- *Environment*: Also dependent upon the above ... using Microstation or AutoCAD or MDS? Blueprints, sketches, etc.
- Collaborative or not?
- Variety of scenarios: Should vary with respect to the kinds of tasks and users of interest. For example, perhaps Scenario 1 is early phase and Scenario 2 is later phase of design. Mixed with this is variety of technologies of interest; e.g., 2D versus 3D views; immersive (egocentric) versus exocentric viewpoints; different kinds of annotation capabilities, layering, symbologies.
- Evaluation of performance: Speed and quality of design (completeness, level of detail, coherence?), tests of knowledge afterwards (e.g., how well can people draw a map of the design or remember it), questionnaires.

SEED Usability and Collaboration

CERL is interested in Carnegie Melon University's (CMU) SEED project (http://seed.edrc.cmu.edu/), which assists in the generation of early design, and how it might relate to the University of Southern California (USC) IMPACT Lab's work on collaborative negotiation. One way to investigate these issues might be to organize students in a semester or year-long project in which many little similar designs are done; students use SEED to do their work and presumably will see reuse in action. With structured scenarios at certain points in which verbal protocols are collected, we could investigate the practices that evolve over time as students do or do not reuse designs and components. If design projects are explicitly collaborative, then describing how students negotiate among options for reusability could be interesting.

Collaborative Design Practices with and without MDS

In a somewhat similar vein, more ethnographic and verbal protocol data about collaborative engineering design are always welcome. Of particular interest is the use of MDS in context. A mock Charrette process in which local CERL or Louisville personnel participate as a design team (e.g., an Owner, Architect, Interior Designer, Project Manager, Mechanical Engineer, Structural Engineer, and Electrical Engineer) could be valuable, especially with a mix of expertise and experience with MDS.

Visual Languages: From Spatial Decomposition to Semantic Networks to Visualization?

The relationship between models and visualizations is always critical. The "ethics of visualization" involves an appropriate, relevant, undistorted view of data; but what is relevant depends on the user and task. In building design, how can we conceptualize the transformation of representations from spatial decomposition hierarchies, to, say, semantic networks, to visualization? Appendix B to this report includes a first cut at visual forms organized around tasks in building design, and incorporates issues of standardization and cognitive tasks with visual representations.

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6. http://www.arch.usyd.edu.au/kcdc/journal/
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11. Cognitive Science http://mitpress.mit.edu/MITECS/
12. A Computational model of Multiple Representations http://www.cs.cmu.edu/afs/andrew.cmu.edu/usr13/al28/camera/TLS_97_1/TLS_97_1.doc
13. Designing for Cognitive Communication: http://www.rrz.uni-koeln.de/themen/cmc/text/roschelle.94.txt
14. Visualizing Design Processes: Structures for Representation, Communication, and Computation http://www.clr.utoronto.ca/PEOPLE/RODNEY/thesis1e.html
15. http://www.arc.cmu.edu/cbpd/semper/pub.html

Appendix A: Charrette Notes from Van Woods

Charrette Observation Notes

Notes based on observation of design charrette on 11/18-11/19 at Fort Hood, TX

Background:

The primary intent of this charrette was to prepare the design of an ECS/Maintenance Building/Warehouse to be built on Fort Hood in FY00 from its current stage of development (predesign) to the next stage in the design process (95 percent) while getting agreement and commitment on the central concept by all of the members involved. Central to the process was the interaction with the user in order to determine and clarify his desires and requirements.

Reference the draft report by Lyle Bohnam, which outlines the MCAR design process, for a description of standard operating procedures of the design process. Other good overviews include pg.8 section C Project Schedule in the Project Management Plan, and the Gantt Chart included in the Agenda packet. Artifacts collected that reflect some of the predesign work that was completed prior to this meeting include (numbered accordingly):

1) DD1391, Military Construction Project Data

2) DD1390 S/1, Guard and Reserve Military Construction

3) Project Management Plan (PMP)

4) Agenda packet

Attendees (see also Attachment 2 Project Management Team in Project Management Plan):

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Michael W. Tarrant
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Foreman
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254-751-0443

Edward W. Schurr
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254-286-6246

Jim Gower
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Dir. Construction
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404-464-8177

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Jesse Kidd
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Bill Welter
DPW-FTES
Fire Dept. Inspector
288-5437
288-5476

Jim Adams
DOIM
Communications Specialist
287-8464

Reference Number:

2, Steve Wright

1, LTC Howard S. Lincoln

16, GW4 Billie R. Gaston

15, CPT Sean P. McDonald

14, Kenneth G. Kempson

13, Michael W. Tarrant

12, Edward W. Schurr

11, Jim Gower

10, Lyle Bonham

9, Mark Ringenberg

8, John Oblak

7, Khanh Le

6, Jose J. Canto

5, Jesse Kidd

4, Alan R. Weimer

3, Patrick Adell

(Entered Later, No Number Assigned in Notes):

Kenneth Slaughter

Bill Welter

Jim Adams

Seating arrangement by reference number (see attachment).

Artifacts Collected:

Items produced at meeting:

Completed Sign-In sheet

2 pieces of "bumwad" sketch paper created by 6.

4, 8.5 x11-in. laser prints of MDS plans created from modifications made to MDS "strawman," and site plan

Table of space allocation

8.5 x11-in. laser-print of MDS 10942Ecs.dba

2 large format site surveys

1 large format site concept with notes

Items Produced Prior to Meeting:

DD1391, Military Construction Project Data

DD1390 S/1, Guard and Reserve Military Construction

Project Management Plan (PMP)

Agenda packet

Media and Tools Used:

Photocopier

Laptop

Phone

Projector

Markers and bumwad

Printed plots

Notes on discussion and activities:

-Lincoln gave the introductions.

-Steve wrote message on board outlining objectives; included produce floor plans, and establish design directives

-Steve continued to describe responsibilities of Louisville district

-Steve explained that if there are other objectives that they wanted to have included that he would add it to the board

-observation that Steve is clearly taking the role of the facilitator at this point and throughout the rest of the time there

-Steve emphasized that "we want to leave with a floor plan"

-introductions around the room

-during introductions, Mike Ferman(?) expressed that his objective was to leave knowing that there was going to be a usable end result

1-question about e-mail

2-asked if 11 was getting messages

2-reviewed minutes

-everyone is seated finally at this point

2-if there is one way, then we will go with it

2-sign off by 13&12

2-wants to wrap up proj management plan by morning (referring to PMP artifact)

2-will distribute draft of PMP for comments (he made copies later and distributed)

8:20am

2-opened up for general comment

2- "It is an open forum. If we get hung up we will move on and things may become clearer"

10-states comments on the charrette process; emphasizes that decisions are made here; everyone agrees that this is it; no backing and filling by designers, however it is iterative; work through until resolved.

10-floor plan and site plan must be locked down

16-we tried to get a hold of DPW

2-resolution "I'll try and make phone calls"

13-one of my biggest concerns is that it is expandable at a future date

4-mentioned MDS/MS problem; mentioned issues with site design

13-we need to turn 180 degrees but we can talk later

16-reiterate importance of expansion; "It may need to double in size"

1-there are studies on way that put this in flux; we have marching orders to design according to 1391; "how can we build this so that it can double in size to minimize impact on cost"

16-review of 1391

10-doesn't have final packet

1-agrees

10-clarifies rational; not significant at this stage

1-telecommunications cost increase

9-what are the costs?

8:30am

9-what are the costs?

16-review specific costs

16-continues specific costs

2-says there is a significant reduction

11-gets up to make copies

13-gets up to bring #'s to 16

10-this is the incorrect #. It should roughly be ....(is calculating)

9-we are talking about an order of magnitude discrepancy

16-gets up to discuss with 2

1&10 have discussion separate from the group; mentions that change needs to be make in ProjDoc

16-total cost is ...

1-if we are short on parking, that will push us over on cost

16-continued review

9-how much was total

16-37

2-used to have warehouse?

16,2-consensus

11-back from making copies

-open discussion-

10-you aren't going to see the # set by congress changing

2-other things to highlight from the 1391?

2-starts to review the project schedule; highlights primary milestone dates

13- this gives us a year to move out

2-will you orchestrate the move?

13-yes

16-brings up the #'s again

2-so main issue is still how big vs. size?

8:40am

1-number is wrong

1-bottom line doesn't change, so #'s have been massaged; we have until Feb. to get it; so we have a couple of months

16-we may need to pull ...

all-reviewing remainder of 1391 and schedule

2-redirects discussion, makes statement that total support facilities # down by ~100,000

1,2,16-consensus

10-according to 11's #'s requirement is 80 ... sq meters

2-we will use that number

9-asks for clarification; “we don’t have a code 6”

10-it’s a code 3

10-technically we can never do that, closes issue

2-any questions remaining on 1391?

16-talks to 1

2-any final questions on schedule?

9-BTO should happened before … do you agree?

6-yes

2-I’ll have to fix PROMISE

15, 14 discuss internally

2-now to review PD

6-puts floorplan up on whiteboard

8-gets involved also; putting up 2 36x48, gives smaller copies to 12&13, 16&15

1-10.76

8-from here on

16-gets up to talk to 11

6-describes justification for layout; not exactly model design; limitation of MDS, sizes available, and in developing elevations; problem in creating sections and elevations, only two types of exterior walls

10-maintenance shops in MDS should be masonry up to certain height and then you get metal; you are having a problem generating?

6-we had problem because of only two options

10-what should happen is the combination masonry wall section should automatically create; if you are having problems with the program we will discuss outside of this meeting; the key issues is that the user has the correct relationships

6-same time wanted to be clear that there are limitations

10-deliberately chosen certain limited selections, let's discuss outside

11-question if you need more workbays

16&1-internal discussion

10-lets move battery room to resolve 13, 12

6-gets up and 10 gets up to the whiteboard

10-suggests alternative

13-I agree, why don't you move

4-on the flammable stg., I have a requirement

13-that is not a problem

13-general comment, sheet of 2 buildings, we want to turn them 180 degrees

10-is there a need for the warehouse to be physically connected?

2-if connected, it could take advantage of a common low bay

11-comment on expanding the warehouse

13-you will need high clearance (pointing at drawing)

2-a piece I think I missed; how is 13 organized

13-ECS warehouse is basis of ECS, stg. Is main driving storage

5-what is ECS?

10-is there traffic back and forth between stg and ... ?

13-definitely

10-close/joined is good but they don't need to be

13-asks for clarification

2-does the stg control parking?

10-yes

2-so you service others?

10-draws on white board some bubble diagrams of relationships between warehouse admin and shop

2-moves drawings to accommodate markers

10-makes another drawing indicating potential future locations (see notes)

10-how big is this thing? Emphasizes that everybody realize what stage in the process they are in; nothing set in stone, the strawman is just an initial concept, it is still changeable

10-strawman is to start us conceptually

5-need traffic in shop

1-how much money delta if you had high roof throughout?

10-heating and cooling is harder then

1-just an idea

10-designers can take a look at that

5-drawing on board

10-visually you have a church

1-OK, I leave the visual stuff to you guys

13-concern, doors must be 16 ft minimum

10-in MDS it is 16 ft

13-are we going to use crane to full length?

10-cost is prohibitive, crane that travels is expensive

13-what is the length of the bay?

1-20x40x2= 20x80

5-72 ft

13-I have a 76 ft truck

general discussion

10-it will be real close

2-what is you r frequency using these vehicles?

13-I've got 56 of them, so all of them practically

10-we've had 80 ft forever and nobody has complained

9:15am

1-is the problem the units? (discussion about virtues of metric vs. imperial units)

12-left the room

1-we are screwed up people (humor)

5-do you serve tanks?

13-yes

13-engineer equipment

10-need different bay width

10-32-ft wide bay

13-it will fit, so I didn't where you are coming from

10-in terms of equipment density

13-probably 10 on hand twice a year

10-so one drive through bay, total bay reconfiguration space

13-not a concern to me

10-OK, not to worry

4-cannot get metric size doors

5-any pit in this area?

13-no pit

5-how do you service trucks?

13- don't want pit, safety hazard

8-we are designing one that does have pits

10-latest ECS was out of an A/E firm in Roanoke

6-3,4 months ago

12-returns with reference materials

10-working on conversion factors

5-let me understand, you need 5 ft for safety, which gives you 86 ft inside required

2-what is that, clarification for 5

5-interesting problem

10,11-how many are there?

General discussion

16-question arose about safety requirement

10-want to have system in ECS; this is a major requirement so wrestling with this

2-ris reduction possible in # of mechanics?

13-resounding no

9:30am

2-humor-maybe you can run a day shift and a night shift

10-running quick #'s, if you take ...

2-alternative solutions, can you park sideways?

2-architect says you need safety

10-this is a standard design, how is it done?

4-this will be over on sq ftg.

13-can we change the standard? And get permission to increase 1391 because changing standard?

16-what about one bay

10-need to run this on every bay

10-let's stay with it and accept tightness and deal with standard in future

5-we need to clarify security

2-we need to get the Fire Marshall involved

2-action item identified

16-given floor plan (referring with 13 on plans on table and pinned up) we have less than 1391 requirements, so we should be able to ...

2-let's take a break and make some calls

8-on the latest one it was not an issue

8-standard design is a standard design, nothing has come up yet

1-10 minute break

5-is it really going to be checked?

6-it will be checked

1-may need to drive over and look at an example here on base

10-is 76 ft exact?

13-no

10-we want to satisfy requirements, we just haven't run across this before

13,10 discussing over plans

1-we can't do half meters with MDS

1-there is rationale for MDS but at times

1-if were are going to compete we need to go metric

10-explains issues surrounding metrics in MDS

1-usually take our standard design

2&9 discuss

10&1 discuss

10-a 16-ft door is not a metric 16-ft door

2-wrote objectives on flip board

5,6-discussing layout ideas over plans

2-adds to objectives list

10,4-talking about metric

13,12-discussing

8,1-discussing

2-getting a second flipboard

2-suggests to throw plans in the middle of the room on a table and to get different groups to discuss

5,6 and 13,16 moved to the middle

10-you have to look at the requirements

(redirection is difficult at this point as most of the attention is at the center of the room)

2-writing more action items

10:00am

5,6-working with plans, scale, and bumwad

highly interactive interaction

5-upper window is security window, only to let light in

everyone else is pretty quiet

2,4,14-went to the middle to discuss

7,6-sketching floorplan on 11x17

electrical designer joins

10,1-talking about MDS problem, may need to create

If fire marshal were here he could tell us exactly.

Kim Slonginger DPW entered.

9-asking if cost can be reduced

10:20am 2&Ken Slonginer, 2 explaining charrette to Ken; he will need to sign off on charrette

midpoint distribution closet

10:40am

(discussion about temperature requirements)

what temperature does it need to be?

1-don't worry about it, don't want to baby them

1&16-what is connected to the computer?

16-I don't think you need air conditioning

concerned about requirements

2-asking to summarize requirements

16-we aren't going to put computers in the center for this project

13-going to put computers here and here

2-do we have a consensus?

2-communication identified requirements; what about sprinklers?

13-going to need plumbing here

13-we'll need 220 single phase here and here

16-need to finalize structural; adjacency requirement for battery room

(everyone working off of strawman at this point)

13-need exhaust here

5-working at desk, sketching on bumwad with thick blue marker on layout

10-enters center area

5-sketching with bumwad on top of strawman using the sizes delineated on the strawman and changing their location

(Blessing is in the middle at this point and I am watching architect #5)

11:20am

10-working on laptop at position 16

A lot of activity in subgroups happening during this time.

7-doing a layout on grid paper

2-overlooking discussion

10-enters middle table discussion with work that he was doing on his laptop dealing with area requirements

11:35am

2-bringing meeting to focus:

2-levitated to consolidated building layout

2-primary is to consolidate facilities, can everyone agree to that? No response.

2-have we missed any large areas?

2-discusses meeting focus for the afternoon

2-opens discussion to the floor for concerns and comments

2-will try to get others (fire, etc.) in to discussion

2-at ... We will need to finish working on site

2-reassurance about offline discussion he had

-Lunch break-

1:00pm

fire inspector representative, William Welter, joins meeting

1-disccusion about heating options w/11&3

10-moved to location 15

2-summerize to William, open to general discussion

13-owner question about how high to put sprinkler above 16-ft racks

2-when do end rack sprinklers kick in?

3-we need to know that; we need to know what the user is storing

2-owner and 13 are to communicate this and to resolve this issue

2&13-discussing uses of stg rack

7-question about how to receive a signal

2-moderating

William-150 ft with sprinkler hookup; reviewing site plan, pressure should be OK, PIV with temperature switch, fire lanes are central, need to sprinkler 100 percent

16-question to William about waiver

William-this is a high hazard classification

2-are there other items?

Ken returns to the meeting.

William-discusses clearance and travel distance

1-we are "making a mountain out of a molehill"

William-it is OK as long as ...

16-what about hydrants?

William-responds

4-I was guessing but I got 4 hydrants, longest line is 700 ft

William-I am still thinking building

William-600 ft distance criteria from building, 150 ft hose length; what about a way to get around the building

Jim Adams, rep. from installation enters meeting

JA looking and assessing 1391, comments that it is pretty high dollar

13&JA to have discussion in back corner of room

11-trying to get definitive on ltg. Requirement

2-are you currently heated (to 13)?

13-yes

2-is this resolved?

1-joking about budget

2-we've sketched, lets review

6-we've been ...

13-first priority is ...

10-working to himself on spreadsheet intensely

site discussion in the back

2:10pm

discussion around the table is finished

13-no hazardous material on site that is handled

10-working on net sq ft

2-redrects discussion

9-I have a question about who do we listen to for estimates?

1-who was that distributed to? (estimate of construction cost)

9-based on 10 percent

2-talking to 8 to say this it is preliminary

2:30-2:45 break

2:50

5-discusses site issues

5-question about equipment cleaning

13-use waco as example

13-what is maximum grad on pkg area?

3:10pm

discussed site, now moving to table to discuss specifics

3:35pm

10-working with 5 and 6 to discuss MDS on how to lay out a design

4:10pm

10-concludes that the designers need MDS training

2-with 15 ft variability

2-what kind of output is required?

10- 8.5 x11-in. will do

10-we can reference the site file

4-is going to "one line" the building in, in order to work in parallel with 10's building development

5-structural engineer is not here, so it may change

owner-tank is the heaviest

4:25pm

2-reviewining action items; any other questions?

7-can we use solar light fixtures?

2-is it based on the life cycle cost?

4-no, based on matching existing project

1-should base on life cycle cost; dislikes lighting being on for 24 hours a day, unnecessary; prefers the concept of using a motion sensor.

10-still working with 5 and 4

owner-concerned about security in relation to lights

16-furniture, question about who would be responsible for wiring modular furniture

10-couple ways to do it, ... ; reserve command headquarters

5-do we need to do a furniture layout?

10-change the default things rather than create from scratch

-request for telecommunications and site in MDS

10-to work on plans that night and 5 to work on site

Meeting done for the day.

11/19/98 (up to tape#6)

8:00am

10-before meeting started, has discussion between 10 and 15 on why the need for an electrical closet

10-wanted to get layout done, but didn't

2-opens by stating the goal of getting signatures; gets signatures now in order to make copies on to plans later in the day

10-noticed that there was no controlled waste

13-I'm OK with it

2,10,4 using laptop

13-need a classroom

1-how many students

13-40-50 students

10-why didn't we get these from requirements documentation

everyone discussing

13-if we can't get it then we will shut down a bay to use a class

10-laughing, lets 5,6,13 huddle around and see if we can resolve this (sitting at 15)

2-talking to 4

10-in the course of working with it I've got a couple of things to talk about

10-talking about structural framing

2-setting up projector, getting help

10-I moved the corridor

10-7967 size finalized

5-I have 2 questions, structure wants to use CMU rather than steel

2-still working to get projector

1-I would be inclined to increase

10-are we going for 1 over sized for 2 separate rooms

user-would prefer 2 rooms

1-its OK if we have room but you are going to have unused space, that not good stewardship

16-if you use partitions you could have double use; you aren't going to have class over luck are you?

13-if you have partitions do you want to have to clan and then have class again?

10-I prefer natural light whenever possible

(taping discussion now)

2&13-talking

13-i have needs for doors; what about bollards?

Site work to center table with owner, Paul Gremela (?), 16, 2, 12

3 subgroups

1, owners telecom reps talking

question about 400 sq ft vault necessity

pointing to screen and using mouse to point

9:20am

2-are we at a point where we can talk to the group?

10-there will need to be some refinement

2-can we get a printout now?

Owner and telecom and designer getting good rapport

2-getting <<arhcite>> (5) to put project label and north arrow on 10's 8.5 x 11-in. printout

using local copiers and printers

13-doors signs, door #'s request; bollards, sink in battery room with hose bib; if grass areas then we need hoses available or sprinkler

4-pointing to site plan

2-can Jose talk about exterior of building?

2-holding up sketch

5-came up to discuss site

13-wants to match exiting color

10-showing color schemes to 13

2-louisville will handle the detailed interior work

16-are we talking about deviating from the standard?

10:00am

13-owner appreciates the process, likes that everyone was listening to his needs rather than convincing him, which is what he expected

1-I will give you what is authorizable and within budget

4-suggesting another budget

10-from here the district will put together 30 percent submittal

10-talking about layout pointing to 8.5 x11-in.

16-is dehumidifier part of module?

10-no, but it is a requirement

10-we need buy in on layout

13-owner is happy

10-pick a color

13-blue

At this point everybody either left or went on tour of ECS that the meeting was being held in to see the features in the building.

Appendix B: Charrette Notes from Blessing Adeoye

Artifacts collected before the meeting

DD1391, 1390S, Project Management Plan (PMP), Master floor plan (8.5X11), Handouts, ECS-DBA (Allowable space allocation), Large size site plan (36X48), Large size survey plan, Small size site plan.

Artifacts collected during the meeting

Data collected with video recorder

Data collected with audio recorder

Sign-in sheet (2 copies)

Allocation of space generated in Excel

Tracing paper (Conceptual drawings)

Artifacts collected after the meeting

A set of MDS generated plans

Handouts

Meeting Minutes

Blessing's notes

Van's notes

Charrette Meeting at Fort Hood, Texas

Date: 11/18 98.

Project: ESC/Maintenance Bldg./Warehouse, Fort Hood

Purpose of charrette:

1. To generate floor and site plans
2. To establish 95 percent design directive
3. To provide for expansion
4. To identify funding/Tele/RCAS

Note: 10 percent project development has been reached.

Many of the participants have not seen a charrette process before; this is their first charrette meeting.

Media Used:

1. White Board
2. Tracing Paper
3. Set of blue prints
4. Flip charts
5. MDS program
6. Writing materials/Notes

Seating Arrangement

<<figure needs to be redrawn>>

A list of attendees, their positions, and seating arrangement.

Seat Number	Name	Position
1	COL Howard Lincoln	
2	Steve Wright	Project Manager/Facilitator of charrette process
3	Patrick Adell	Mechanical Engineer
4	Alan Weimer	Civil Engineer
5	Jessie Kidd	Architect

6	Jose Canto	Architect
7	Kahn Le	Electrical Engineer
8	John Oblak	Engineer Manager
9	Mark Ringenberg	Project Manager
10	Lyle Bonham	MDS Manager
10b	Walter ?	Joined late
11	Jim	
12	Ed	Site plan manager
13	Mark	
14	Kenneth Kempson	Tel Com specialist (represents users)
15	CPT Sean McDonalds	
16	COL Billie Gaston	Installation Chief

Steve Wright started with self-introduction and introduction of researchers from CERL. This is going to be an open forum. At the end of the day, we will generate a list of action plans said. Steve requested everyone to give a brief self-introduction (round table introduction). He went over the agenda of the day.

General comments

#10 - Everyone has to come to an agreement on decisions made today. Site and floor plans have to be completed.

Review of 1391

CW4 Billie Gaston started discussion on reviewing of 1391. He gave an updated of 1391 in metric and English units.

#2 & #16 - Talked back and forth. There are discrepancies in figures. More parking spaces are needed. Sizes of the warehouse rack and parking spaces need to be reconsidered. Other space requirements are OK.

Note: There are a lot of talking back and forth between #s 2, 1, and 16.

#13 - Some of solutions may be to move activities around within the space, but if we turn the drawing around, it will affect some activities (He was talking about orientation of the building).

Review Project Schedule

#2 - Went over the project schedules. He read the scheduled dates for various activities. He indicates that the design is schedule to be complete and ready to be advertised by the end of 1999. "There are some juggling of sizes in space requirements"

#9 - We have no code2**

#6 - Asked question about BTA**

#8 - Brought a set of blue prints and mounted some on the wall while some were laid on the tables. Let us take a look at these drawings and review against design criteria. Note that changes in 1391 will change some of the layouts.

#6 - Presented the drawing and explained so the group can understand. Using MDS have posed some limitations in this design he said. You have a few modules to work with, elevation drawings are not easy and sections cannot be drawn using MDS.

#10 - Let us not dwell on the limitations of MDS at this point. MDS was delivered with limited building system's capability. The program was originally produced to meet the need of Army Reserve. We need to go over what we have here and we can address MDS limitations later on. I can meet with you personally to discuss the problems. Some solutions may be to move some spaces around.

After a short break

Drawings were laid on the table for critic. Dimensions were verified. Problems such as circulation and relationship of spaces ere discussed. Design alternatives ere explored. (#4, #14, #2, and #6 were involved in this initial discussion).

#14 raised a concern about telecommunication needs in the bay area. He said, "we need to have LAN capability, telephone connection, and servers in the bay area.

#6 laid a tracing paper on the original drawing and started sketching out some design alternatives. #7 was invited t the table to address some telecommunication issues.

Note: At this time two other small groups' discussion were going on in the room.

Artifacts generated at this point are:

1. Marked up plans

2. Design alternatives

Action items generated are:

1. 1391 - perspective on parking. 7525 are small versus 80937

2. Limitations of MDS on CMU/metal

3. Circulation problems

4. Code 6 plus design funds.

#6 - Came up with a new sketch (plan). It is better to stay with the original drawing a minor modification. He addressed the issues of accessibility and space locations in his new plan. The new layout shows a new interior access to the maintenance, warehouse, and the bay area.

Note: A new person came in (Ken Slaughter from DPW, a user's representative).

Discussion of Site Layout

#4 - Mounted the site plans on the wall. He explained the site plan concepts.

#13 - (Was looking at the site plan) I am more concerned about the expandability of the building in the future.

#4 - I am a new engineer on this project. I am willing to modify the site plan to accommodate expansion.

*#1 - A study is coming up on how to build according to the requirements of 1391. How can design be efficient and cost effective?

#16 - Explained, 1391 is a document that deals with facility types.

#10 - I noticed some discrepancies in 1391 and the cost estimate sheets.

[Some individual discussions were going on].

#2 - Looking at the space requirements, there are some significant reduction in some area allocation.

There was an agreement to combine both buildings into one. The three main areas of the building are the maintenance, warehouse, and administrative.

After Lunch Break - Discussion of Warehouse

Lead by Jose Canto #6

Jose mounted the drawing on the wall and explained the relationship of the spaces.

Jim Adams (#11?) - Represent installations for electrical issues. Jim asked how the heating of the warehouse would be handled.

10b - Joined right before lunch. We need to make sure that fire alarm systems and sprinklers are being considered. Also, How easy is it to access the building

In case of fire or emergency? I'll suggest <<tampa>> switches and separate zones.

[During this discussion, Jose was busy working on new designs].

#10 - Talked briefly about the relationship of activities and space requirements. "Take a close look at the number of the base and equipment," he said.

#13 - Responded, "That was not a problem or a serious issue. Let us look at the size, safety issue, issues related to metric versus English units.

#6 - Clarified the safety issue. We need to get a fire Marshall involved.

Key players were called back to the table to review Jose's update.

Jose presented new sketches of the floor plan. He sketched out 3D perspective drawing of the design. He modified the original drawing and came up with a modified concept. More administrative spaces were added. He also moved around some spaces. New ideas show they gained more spaces. The administrative area will be single story with low roof; this area will serve other adjacent areas. A separate break room and a classroom replace the break/classroom. Also, an additional storage is provided.

#10 (Lyle) and #16 were on Lyle's lap top going through some space requirement listing in MDS.

#10 & #16 joined the people on the table. Looking at the drawing, #10 said, "In this kind of situation, I tried to stay away from involving in the critic of other people's design.

In this new sketch, there are a few things that may be a little difficult to accomplish using MDS, for instance 6-ft wide corridor.

#16 - I also noticed a discrepancy in the size of the vault. The original space was about 55,000. The new sketch is showing about 60,000. Some spaces are not the same as the space requirements.

#10 - How many people are associated with the warehouse?

The group was looking at the space requirement sheet

#16 - 220 SF office. We will need more administrative offices in the future. We will need more storage facility as well.

The group was discussing which spaces to move around to accommodate more storage.

#10- What goes in this storage room?

#16 - You can go down stair right now and see what we got. They are tons of manuals.

#6 - While discussion continued, #6 was busy sketching to address some of the questions.

#6 and #10 were working together on a laptop going through space requirements in MDS.

Note (Different unstructured small group discussions were going on - difficult to record anything).

—

#7 & #14

#14 brought the following issues up:

1. Distribution points are too far away because of distance

2. No pit/use floor jack

3. Connectivity of two facilities

4. Usability of the areas

5. LAN/Telephone capability

6. Sharing spaces between bay areas

My first concern as a user is the telecommunication needs in this facility.

#7 - Do we need telephone, LAN, and servers in the bay area?

#14 - Yes, I need it for my customer.

#7 - I don't think these are needed in this facility; I need to find out more about this.

#14 - Look, you are not listening to me. I am telling you what we need.

#7 and #14 now joined other group members at the center of the room

#14 - There is no plans to provide air-condition in the bay area.

#16 - Why do you need air-condition in the bay area?

#14 - The equipment in this area need to be cooled with air-condition.

#7 - Let us address the issues of LAN, and servers in the bay area. The users have raised a concern about this. They are looking into making the facility technologically competent in the future.

#14 - I am going to live with whatever you design later on so I want all the needs to be considered now.

#10 - What about locating the building in two separate locations?

#14 - That is a possibility, but ... (Sentence was not completed).

#16 - OK. Let's summarize what we got. No computers and servers in the bay area. It is not a requirement.

#1 - What type of HVAC do we have in this facility?

#3 -The existing system is "overhead system." The new design will be better with floor models, underfloor system, plastic tube and boiler because of tornado.

I will some research on this.

#11 - We need requirements for battery shop. There is no need for hazardous material handling. "What is the square footage of this space?"

#10 - The space is 11,840 net sq ft. Warehouse is about 57,800 SF.

(#10 was reading the space requirement from MDS database information). "If I can find a computer with a printer connection, I will generate some figures for everyone" said #10.

#1 - Look at the drawing, "everything is treated as Army's space"??

Recommendations

Increase the roof height of the warehouse

A drive to be provided (Run from the E to W).

Discussion on Site Layout continued (Lead by #4)

#4 - We need to have about 20 acres. Vehicular access to the site and the warehouse is very important. Also, there is a discrepancy in the requirements. I will get information from the users to provide a better vehicular access. Explained the parking requirements. Thirty-nine parking spaces are provided.

#9 - I think we have 39 occupants, think about visitors, and increase parking space to 55. Are we providing for washing racks? What is washing rack? It is a cleaning/vehicle washing area. We need enough clearance for back out and driving of vehicles. We have some large vehicles that we be making turns.

There was a breakout session here

#10 - Showed space allocation. Explained some of the space requirements to other architects (#s 5 and 6). Gave out copies of spreadsheet and MDS database outputs. He loaded a pre-designed drawing in MDS and demonstrated how to use MDS. A floor plan was generated with MDS.

#6 - Explained some of new changes to the floor plan

The administrative area will be single story with low roof; this area will serve other adjacent areas. A separate break room and a classroom replace the break/classroom. Also, an additional storage is provided.

Final Discussion on 11/18

Furniture/Procurement

#2 - UNICOR was recommended and approved by #s 1 and supported by #10. This responsibility should be spelled out in the contract document. #16 indicated that the funds would be provided with OMAR. #2 and #10 recommended Louisville District to handle the furniture procurement. Now, that we've agreed unanimously on the layout, #10 will reproduce the layout in MDS and bring copies for everyone tomorrow. Meeting is adjourned till 8 a.m. tomorrow.

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11
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14. ABSTRACT

Architects and engineers create and communicate in a highly visual environment; the way they visualize their designs and communicate throughout the design-construction process fundamentally affects the quality and flow of work in the construction project. Such collaborating disciplines require specific forms of support to coordinate their efforts, communicate, and resolve conflicts.

This work hypothesizes that good visualization depends on a contextual approach, that is to say, good visualization depends upon the context of the task, user, and environment. The study established a theoretical basis for the relationship of visualization to the cognitive and collaborative process that occurs in the facility life-cycle process through a presentation of a range of experiment and observation. The study also presented the roles of visualization in collaborative engineering design, specifically emphasizing ethnographic and scenario-based simulation studies, with supplemental interviews and questionnaires.

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